PEEBLES

The Losses in the Process of

Converting the Energy of Coal into Steam

Mechanical Engineer

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THE LOSSES IN THE PROCESS OF CONVERTING THE ENERGY OF COAL INTO STEAM

BY

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THESIS

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Thomas Armstrong Peebles

ENTITLED The Losses in the Process of Converting the Energy of Coal into Steam

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Mechanical Engineer

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THE LOSSES IN THE PROCESS OF CONVERTING THE ENERGY OF COAL INTO STEAM.

1. INTRODUCTION.

The average manufacturing plant spends less than one percent of the value of its finished product for fuel. So long as the operating engineer keeps the power plant in condition to meet the demands of the factory for power, light and steam, the manager is willing to forget that department and devote his time and attention to manufacturing problems. Realizing that there are large savings to be effected by improved methods or the use of special machinery in the production departments, the manager works and thinks along these lines and is not usually interested in improving the efficiency of a department which represents a small part of the total operating cost of the plant. As a result, the efficiency of the power generating process in such plants is often very low.

The central station, which within recent years has become an important part of our industrial organization, spends fifty percent or more of the value of its product for fuel, and the economical transformation of the energy of the fuel into work is the most important problem that confronts the central station manager.

Turbines, engines, generators, condensers, etc. can be designed to give certain predetermined results as to capacity and efficiency and if kept in a proper state of repair, will closely approximate these results in daily operation. The question of economy in the transformation of the energy of steam into electrical energy is, therefore, settled when the type of equipment is decided upon, and whether the economy is good or bad, depends upon the judgment with which the selection is made.

The efficient generation of steam is an entirely different problem. The best of judgment may be used in the selection of equipment but it does not follow that good results will be secured in daily operation. Furnaces and boilers have no "characteristic curves" of performance. On the contrary, they are very sensitive to local conditions, it being not only possible but of daily occurrence in many plants that the same boiler and furnace may be operated for part of the day at a given efficiency and at other times during the day, at not more than half that efficiency. It is, therefore, imperative that the steam generating process be given careful and constant supervision.

To determine the performance of a steam generating unit, evaporative tests are run and the efficiency of the process is calculated from the test data. This efficiency which is known as combined efficiency of boiler and grate, is defined in the code of the American Society of Mechanical Engineers as the ratio of the heat actually absorbed by the boiler per pound of dry coal to the heat energy in one pound of dry coal. If a test shows 65% combined efficiency, it means that 65% of the heat units in the dry coal were utilized and the question "what became of the other 35% ?" at once arises. The method of analyzing tests on a basis of combined efficiency gives no clew to these losses and fails to show the engineer who is interested in proving the efficiency of steam generation where to begin.

There are two distinct and independent processes in the generation of steam from coal: first, the transformation of the energy of coal into heat which is the function of the furnace; and second, the absorption of this heat by the boiler. Each process must be considered separately and the nature of the losses in each

analyzed before intelligent action can be taken to reduce these losses.

Dry coal is a theoretical substance so far as actual steam generating is concerned and the analysis of conditions should be based on coal as fired because the moisture content, which runs as high as twenty-five percent in some commercial fuels, has an important bearing on the value of a fuel and the losses encountered in its burning.

II. NECESSARY LOSSES.

Nature imposes certain restrictions which render it impossible to utilize all the heat energy of coal in the generation of steam even under theoretically perfect conditions. The first step in analyzing losses is, therefore, a consideration of the necessary loss in connection with a perfect furnace burning pure carbon and a perfect boiler absorbing the heat.

A perfect furnace would effect the complete combustion of carbon with the theoretical amount of air necessary to supply the oxygen for this combustion. The fuel which is pure carbon combines with the oxygen of the air to form CO_2. The gaseous products of combustion leaving the furnace would contain 20.91% by volume of CO_2 and 79.09% by volume of N, making a total of 100%. The weight of gas per pound of C may be found from the combining weights of C and O and the relative densities of CO_2 and N as follows:

$$CO_2 = 12 + (2 \times 16) = 44$$

$$C \text{ in } CO_2 = \frac{12}{44} CO_2 = \frac{3}{11} CO_2$$

$$\frac{CO_2 + N}{C} = \text{Weight of gas per unit weight of C}$$

$$(1) = \frac{CO_2 + N}{\frac{3}{11} CO_2}$$

The relative densities are $CO_2 = 11$
$N = 7$

Multiplying equation (1) by these values for relative densities, we have:

$$(2)\ \frac{11\ CO_2 + 7\ N}{3\ CO_2} = \text{weight of gas per pound C in which } CO_2 \text{ and } N$$

are percentages of volume.

For perfect combustion of C with the theoretical amount of air, $CO_2 = 20.91$; $N = 79.09$

$$\text{Weight of gas per pound of C} = \frac{(11 \times 20.91) + (7 \times 79.09)}{3 \times 20.91} = 12.5\#$$

This figure does not agree exactly with that calculated from the accurate combining weights, but is used here because it was calculated from the values of relative densities which are commonly used in the solution of combustion problems in commercial work.

The hot gas passing over the heating surface of a perfect boiler would be cooled down to the temperature of steam corresponding to the boiler pressure, but this temperature is higher than the temperature at which the air and C enter the furnace and there is, therefore, a loss of heat which can never be eliminated. For every pound of C burned, 12.5 lbs. of gas are generated and the loss in B.t.u. may be expressed as

$$(3)\ 12.5 \times .24\ (T_p - T_a) = 3(T_p - T_a)$$

in which T_p and T_a are the temperatures of the steam and air respectively. If the working pressure for example be 200 lbs. absolute, $T_p = 381.9°$ F. Assume $T_a = 62°$ F. Then, necessary loss under ideal conditions $= 3\ (381.9 - 62) = 975.7$ B.t.u.

When coal is the fuel, two other sources of loss occur: first, loss due to the evaporation of the moisture contained in the coal, and superheating the steam thus formed to the tempera-

ture corresponding to the steam pressure; and second, loss due to the escape as superheated steam formed by burning the H of the fuel. These losses may be calculated as follows:

H_2O = % moisture in coal as fired.

H = % H " " " "

.50 in Specific heat of superheated steam.

Loss due to H_2O in coal =

(4) $$\frac{H_2O}{100}\left\{ (212 - Ta) + 970.4 + .50\ (Tp - 212) \right\}$$

Loss due to H in coal =

(5) $$\frac{9\ H}{100}\left\{ (212 - Ta) + 970.4 + .50\ (Tp - 212) \right\}$$

In which 9 H = H_2O formed by the burning of H

These losses may be expressed in one equation.

(6) $$\left(\frac{H_2O + 9\ H}{100} \right)\left\{ (212 - Ta) + 970.4 + .50\ (Tp - 212) \right\}$$

This loss varies widely with different coals, for example,

(a) In the case of New River or Pocahontas coal containing -

2% H_2O

4.5% H

The expression $\left(\frac{H_2O + 9\ H}{100}\right)$ = .425

(b) With Colorado Lignite, containing -

22% H_2O

5% H

The expression $\left(\frac{H_2O + 9\ H}{100}\right)$ = .67

Under the same conditions, the loss due to H_2O and H will be about 57% greater with Colorado Lignite than with Pocahontas or New River coal. The necessary furnace losses may be summed up as follows:

(a) Loss due to theoretical amount of dry gases being heated from T_s to T_p = 3. $(T_p - T_a)$ per lb. C or

(7) Loss per pound coal = $3\ C_b\ (T_p - T_a)$ where C_b = C burned per pound coal.

(b) Loss due to H_2O and H =

(8) $$\frac{(H_2O + 9\ H)}{100} \left\{ (212 - T_a) + 970.4 + .50(\ T_p - 212) \right\}$$

The sum of losses (a) and (b) deducted from the total heat in one pound of coal as fired, gives the heat available for the unit and the "Highest Theoretical Efficiency" =

$$\frac{\text{Heat Available for Unit per Pound Coal as Fired}}{\text{Heat in One Pound of Coal as Fired}}.$$

III. FURNACE LOSSES.

In actual practice, there are additional losses which depend upon the design of furnace and boiler and the method of operation. For the purpose of analysis, these losses are divided into furnace losses and boiler losses.

The furnace losses are due to -

(a) Admission of an excess of air above that theoretically required for complete combustion, indicated by O in the furnace gases.

(b) Incomplete combustion of the combustible leaving the grate surface indicated by CO in the furnace gases.

(c) Incomplete extraction of the Carbon from the fuel.

(d) Discharge of refuse from the furnace at high temperature.

Loss (a) The furnace gases contain O and sometimes CO and equation (2) foran actual furnace takes the form -

(9) $$\frac{11\ CO_2 + 8\ O + 7(\ CO + N)}{3(CO_2 + CO)}$$

Weight of gas per pound of coal as fired =

(10) $$\left(\frac{11\ CO_2 + 8\ O + 7(\ CO + N)}{3(CO_2 + CO)} \right) C_b$$

where Cb = pounds of C burned per pound of coal as fired.

The heat contained in the flue gas from the temperature of the atmosphere up to the temperature of the steam =

$$(11)\quad \left(\frac{11\,CO_2 + 8\,O + 7(CO + N)}{3(CO_2 + CO)}\right) Cb \times .24\,(Tp - Ta)$$

Equation (11) - Equation (2) gives the loss due to excess air =

$$(12)\quad \left[\left(\frac{11\,CO_2 + 8\,O + 7(CO + N)}{3(CO_2 + CO)}\right) Cb \times .24\,(Tp - Ta)\right] - 3Cb\,(Tp - Ta)$$

Loss (b) The loss due to incomplete combustion is determined as follows:

$$C \text{ in } CO = \frac{3}{7}\,CO$$

$$C \text{ in } CO_2 = \frac{3}{11}\,CO_2$$

$$C \text{ in gas} = \frac{3}{7}\,CO + \frac{3}{11}\,CO_2$$

$$\frac{\frac{3}{7}\,CO}{\frac{3}{7}\,CO + \frac{3}{11}\,CO_2} = \text{proportional part of C remaining in the form of CO}$$

Multiplying each member by its relative density, this expression reduces to $\left(\frac{CO}{CO + CO_2}\right)$ = pounds of C in CO per pound of C burned.

The combustion of one pound of C contained in CO to CO_2 generates 10150 B.t.u. The loss due to CO per pound C =

$$\left(\frac{CO}{CO + CO_2}\right) \times 10150$$

Loss per pound of coal as fired =

$$(13)\quad \left(\frac{CO}{CO + CO_2}\right) \times 10150 \times Cb$$

Loss (c) The loss due to the presence of C in the refuse = [Wt. of refuse per pound of coal as fired - Wt. of ash per pound of coal as fired] x 14500.

Some carbon is carried over with the furnace gases and is

deposited in the combustion chamber of the boiler or is discharged from the stack. Under ordinary conditions, this loss is negligible but there are conditions, particularly when forced draft is used, under which as much as two percent of the fuel is lost in this manner. This loss is sometimes spoken of as the "Loss due to Production of Cinders".

Loss (d) The temperature of refuse discharged from a furnace varies considerably with different methods of firing. The specific heat may be taken as .28 and the loss per pound of coal as fired = Wt. of refuse per pound of coal as fired x .28 x (Tr- Ta) in which Tr = temperature of the refuse.

An average value of (Tr-Ta) is 1800°F. and this value may be used if a suitable pyrometer for an actual determination is not available.

The sum of these losses is deducted from the total heat available for the unit and the remainder is available for the boiler.

The furnace efficiency may be expressed as

$$\frac{\text{Heat available for the unit - Furnace losses}}{\text{Heat available for unit.}}$$

This is the most important item in the steam generating process because it is the most sensitive to local conditions and with the methods of operation in vogue at most plants, represents the largest avoidable loss.

IV. BOILER LOSSES.

The boiler losses are:

(a) Loss due to temperature of the gases above Tp

(b) Loss due to leakage of air through the boiler setting.

(c) Loss due to radiation and unaccounted for.

Loss (a) In practice, the gases leave the boiler at a temperature above that of the steam and a loss of heat results which must be charged to the boiler. The weight of dry gases may be found from equation (10) and the weight of superheated steam due to H_2O and H in the coal from the expression $\left(\frac{H_2O + 9\,H}{100}\right)$

Equation (10) x specific heat of dry gas = B.t.u. lost per degree of difference in temperature between the flue gas and the steam = $\frac{11\,CO_2 + 8\,O + 7\,(CO + N)}{3(CO_2 + CO)} \times .24\,Cb$

$.50\left(\frac{H_2O + 9H}{100}\right)$ = B.t.u. loss per degree difference in temperature between the flue gas and the steam, due to H_2O in the flue gas; in which .50 = average specific heat of superheated steam.

Total loss for a given range in temperature =

$$\left[\left(\frac{11\,CO_2 + 8\,O + 7(CO + N)}{3\,(CO_2 + CO)}\right) \times .24\,Cb + .50\left(\frac{H_2O + 9\,H}{100}\right)\right] \times (Tf - Tp)$$

in which Tf = temperature of the flue gas.

Loss (b) Equation (10) gives the weight of gas per pound of coal as fired when the analysis of the gas is known. Simultaneous analyses at the furnace and at the flue may be taken and the weight of gas at each point calculated from which the infiltration may be determined. The loss due to this infiltration = pounds of infiltration per pound of coal as fired x .24 (Tf - Ta)

Loss (c) The sum of all losses - the heat absorbed by the boiler will be less than the total heat in the fuel and the difference is charged to radiation and unaccounted for loss.

The losses mentioned above may be grouped as follows:

V. SUMMATION OF LOSSES.

(a) Heat absorbed by moisture and H_2O from burned H up to Tp.

(b) Heat absorbed by theoretical amount of dry gases up to Tp.

FURNACE LOSSES.

(a) Heat loss due to excess air up to Tp.

(b) Heat loss due to incomplete combustion.

(c) Heat loss due to incomplete extraction of carbon from the fuel.

(d) Heat loss due to discharge of refuse from the furnace at high temperature.

BOILER LOSSES.

(a) Heat loss due to temperature of gases above Tp.

(b) Heat loss due to leakage through boiler setting.

(c) Heat loss due to radiation and unaccounted for.

The necessary losses can never be reduced and are of interest only since they determine the maximum theoretical efficiency.

VI. DISCUSSION OF FURNACE LOSSES.

It is almost invariably the case that the whole steam generating process is or is not efficient, depending upon whether or not the furnace losses are reduced to a minimum. The point of minimum furnace losses differs for almost every design of furnace and grade of coal and must be determined for each set of conditions. The three furnace losses depend to a certain extent upon one another and a reduction of one loss may result in the increase of the others by such an amount that the sum of all will increase.

The most striking illustration of this is the large increase in the loss due to excess air which results from an effort to reduce the combustible in the ash. The man who buys coal for the purpose of generating steam naturally wants to have it burned up as

completely as possible and often judges the work of his firemen by the appearance of the ash pit. He demands that the coke in the ash be reduced to a minimum, and to accomplish this, the firemen are compelled to admit a large excess of air. By so doing, they can probably reduce the ash pit loss by two percent of the total coal burned but the increased loss due to excess air will be from five to ten times as great as the saving due to more complete extraction of carbon from the ash. Exactly this condition exists in hundreds of boiler plants.

An attempt to reduce the excess air loss will result in a loss due to incomplete combustion if the reduction of air supply is carried too far. This is especially true of high volatile, free-burning coals. A series of evaporative tests, during which careful attention is given to the analysis of furnace gases, is necessary to determine the most economical amount of air. In general, it may be said that the instant CO appears in the gas analysis, it is time to stop the reduction of the air supply. In some cases, this occurs when the gas contains 10% of CO_2 and in other cases, the CO_2 may be carried up to 17% before CO appears. A good rule to follow is "Screw up the CO_2 till CO appears and then back off or turn".

The percentage of CO_2 that can be obtained without the presence of CO depends upon the size of furnace, provision for proper mixing of the gases, rate of combustion, and character of fuel as regards combustible volatile. Figure 1. shows a furnace which has given over 15% of CO_2 over an eight-hour period without more than a trace of CO when burning West Virginia coal having 18% of combustible volatile at a rate of forty pounds of coal per square foot of grate surface per hour. If Illinois coal, which contains over 30% of combustible volatile be burned at the same rate in this

furnace, the CO_2 could not be carried above 10% without the presence of CO. A furnace can be designed to burn Illinois coal with high percentages of CO_2 and no CO but purchasers are not as yet educated to the point where they will spend the amount of money necessary to construct such a furnace. Figure 2. shows such a design. This furnace provides a long flame travel, large combustion chamber, and thorough mixing of the furnace gases, all of which are necessary for complete combustion with the minimum amount of air. Furnace design is rapidly developing along these lines and the efficiency with which high volatile coals can be burned is increasing.

When the necessary experimental work has been done to determine the most economical conditions for a given furnace, accurate records of furnace performance should be kept. These records should include furnace draft, rate of combustion per square foot of grate surface, gas analysis, and occasional ash analysis, and the most economical conditions should be maintained as nearly as possible. Strict adherence to such a program will increase the efficiency of operation of the average furnace by at least ten per-cent.

Test sheet No. 1 shows the results secured on a furnace of such design that it is capable of burning about thirty-five pounds of 17% volatile coal per square foot of grate surface per hour with 12% CO_2 and no CO and without the production of objectionable smoke. Test sheets No. 2 and No. 3 show the results of running this same furnace under conditions producing 8% CO_2 and 16% respectively. In the first case, the slight decrease in the losses due to elimination of CO and reduction of combustible in the ash are more than offset by the increased loss due to excess air; and in the second case, the decreased loss due to excess air is more than

offset by the increased loss due to production of CO and the increase in the unaccounted for loss. These results show that for any given coal and rate of combustion there are certain well defined limits within which the air supply must be kept if satisfactory efficiency is to be secured.

Test No. 4 shows the result of attempting to burn 33% volatile coal at the same rate in a similar furnace. In addition to the low efficiency secured, black smoke was produced continually. This comparison shows the necessity of proportioning the furnace to suit the rate of combustion and the kind of coal to be burned, the weight of volatile gases that must be consumed in a given time, determining the size and shape of furnace required.

If an analysis of losses is to be of value, the method of calculations must be simplified and arranged in such a way that the results may be readily calculated. The "Methods of Calculating Results of Boiler Tests" presented here give the necessary formulae worked out in natural order and by their use, complete calculations of a test may be made without the assistance of handbooks or other data. With the exception of the ultimate analysis of the coal, all the data required are readily obtained in a plant which has one boiler equipped for tests. It is now well known that the ultimate analysis of pure coal from any seam varies but slightly and if the origin of a coal be known, an accurate ultimate analysis may be secured from one of the Government publications of coal analyses.

The complete analyses of a number of tests given herewith show the efficiency of each step in the steam generating process and establish the limits of good practice.

The necessity of a separate analysis of the functinns of furnace and boiler was suggested to the writer in his work with the

Green Engineering Co. It has been the practice to include in stoker contracts a guarantee of the combined efficiency of boiler and furnace but this often is decidedly unfair as it involves the performance of apparatus furnished by others. The Green Engineering Co. has made a specialty of the engineering problems relating to boiler and furnace performance and can predict very accurately what results will be secured from a new installation of any design of furnace when applied to any type of boiler on the market. When old boilers are equipped with stokers the results cannot be accurately predicted because the existing conditions of boilers, settings, breeching and stack introduce unknown conditions. It, therefore, appeared that a guarantee of furnace efficiency only should be made, as the stoker and furnace should not be charged with losses due to leaky brickwork and dirty boilers. The Green Engineering Co. has recently based some guarantees on furnace efficiency and now prefers this type of guarantee to the old combined efficiency method.

VII METHODS OF CALCULATING RESULTS OF BOILER TESTS.

Item

4 to 8. Get information from Chief Engineer of plant or from setting drawing.

9. Get information from setting drawing.

11 to 20. Average readings. Item 13 = Item 11 + Item 12

24. $\frac{\text{Item } 23}{\text{Item } 2}$

25. Item 24 x $\left(\frac{100 - H_2O \text{ in Coal}}{100} \right)$

26. $\frac{\text{Item } 24}{\text{Item } 9}$

28. Item 25 x Item 2 - [Item 27 + Item 46a]

30. $\frac{\text{Item } 29}{\text{Item } 2}$

31. $\frac{\text{Total heat in dry steam + heat in superheat - heat in feedwater above } 32°F.}{970.4}$

32. Item 30 x Item 31

33. For wet steam only from calorimeter

35. $\frac{\text{Item } 32}{34.5}$

36. Hourly checks must be carefully made to insure accuracy of this item.

37. $\frac{\text{Item } 35}{\text{Item } 34}$

38. $\frac{\text{Item } 7}{\text{Item } 35}$

39. $\frac{\text{Item } 29}{\text{Item } 23}$

40. $\frac{\text{Item } 30}{\text{Item } 25}$

41. $\frac{\text{Item } 32}{\text{Item } 24}$

42. $\frac{\text{Item } 32}{\text{Item } 25}$

43. $\frac{\text{Item } 32 \text{ x Item } 2}{\text{Item } 28}$

44. $\left\{ \frac{11\, CO_2 + 8\, O + 7(CO + N)}{3(CO_2 + CO)} \right\} \times \left\{ (\% \text{ C in actual coal-Item } 47) - \left(\frac{\text{Refuse \% actual coal - \% ash in actual coal}}{100} \right) \right\} + \frac{35.8 \text{ H per lb. Coal}}{100}$

45. Use table or curve   46-B $\dfrac{\text{Item 46-A}}{\text{Item 23}}$

47. Laboratory Analysis

49. (Item 41 x 970.4) - (Item 39 x (Hs-Ht))   50. Item 39 x(Hs-Ht)

51. $\left(\dfrac{H_2O + 9H}{100}\right) \times \left\{ (212-Ta) + 970.4 + .50(Tp - 212) \right\}$

52. 12.52 Cb x .24 (Tp-Ta) or 3 Cb (Tp-Ta)

53. Item 48 - (Item 51 + Item 52)   54. $\dfrac{\text{Item 53}}{\text{Item 48}}$

55. (Refuse per lb.actual coal - Ash per lb.actual coal) x 14500 + (1800 x .28 x refuse per lb. actual coal)

56. $\left(\dfrac{11.CO_2 + 8\,O + 7(CO + N)}{3(CO_2 + CO)}\right)$ at furnace x Cb x .24(Tp-Ta) - Item 52.

57. $\left(\dfrac{CO}{CO + CO_2}\right)$ at flue x 10150 x Cb   58. Item 47 x 145

59. Item 53 - Items (55 + 56 + 57 + 58)   60. $\dfrac{\text{Item 59}}{\text{Item 53}}$

61. $\left[\left(\dfrac{11\,CO_2 + 8\,O + 7(CO + N)}{3(CO_2 + CO)}\right) \times .24\,CB + .50\left(\dfrac{H_2O + 9H}{100}\right)\right] \times$

(Tf - Tp)

62. [(Lbs.gas per lb.C. at flue) - (Lbs.gas per lb.C.at furnace)]

x .24 Cb (Tf - Ta)

63. Item 59 - Items (49 + 50 + 61 + 62)

64. $\dfrac{\text{Item (49 + 50)}}{\text{Item 59}}$ 65. $\dfrac{\text{Item (49 + 50)}}{\text{Item 48}}$ or

Item (54 x 60 x 64)

ABBREVIATIONS.

Ta	= Temp. of air in boiler room
Tp	= Temp. corresponding to steam pressure
Tf	= Temp. of gases in flue
Cb	= Carbon burned per lb. actual coal
Sp.Ht.	= Specific Heat of the steam
Ts	= Temp. of steam as superheated
Hs	= Total heat in superheated steam
Ht	= Total heat in dry steam at observed pressure

VIII. REPORT OF BOILER TEST WITH ANALYSIS OF HEAT LOSSES.

1.	Run from		8 AM to 4 PM
2.	Duration of test		8 hours
3.	No. of boilers used		one
4.	Type of boiler		W.T.
5.	No. of tubes		
6.	Diameter of tubes		4"
7.	Water Heating Surface	Sq.Ft	6386
8.	Superheating Surface	Sq.Ft	760
9.	Grate Surface	Sq.Ft	115
10.	Ratio Grate surface to Water Heating Surface	1 to.	55.5
11.	Steam gauge pressure	lbs.	199.7
12.	Atmospheric pressure	lbs.	14.7
13.	Absolute steam pressure	lbs.	214.4
14.	Draft suction at uptake	inches	1.023
15.	Draft suction over fire	inches	.562
16.	Draft pressure under fire	inches	
17.	Avg.temp.boiler room	°F	89.3
18.	" " flue gases	°F	579.3
19.	" " feed water	°F	178.5
20.	" " steam.......Tp..387.7..Ts	°F	557

21. Name of Fuel. West Virginia Semi-Bituminous

22. Size of Fuel. Slack

PROXIMATE ANALYSIS					B.t.u.	ULTIMATE ANALYSIS		
H_2O	V.M.	F.C.	Ash	S.	per pound	C.	H.	S.
					fired 13785	78.0	3.54	
2.2	16.2	72.7	8.9		dry 14095			
					comb. 15500			

ASH		FLUE GAS				
% Comb.in Refuse	Refuse % Coal Fired		CO_2	O	CO	N etc.
		1st pass	13.3	5.7	0.1	80.9
	11.47	flue	10.4	8.0	0.0	81.0
22.35	Refuse % Dry Coal					
	11.71					

23.	Coal burned total run actual	lbs.	33376
24.	Coal burned per hour actual	lbs.	4172
25.	Coal burned per hour dry	lbs.	4080
26.	Coal burned per hour per sq.ft.g.s.actual	lbs.	36.28
27.	Total weight of refuse	lbs.	3825
28.	Total weight of combustible	lbs.	27814
29.	Water evap.total run actual	lbs.	296160
30.	Water evap.per hour actual	lbs.	37020
31.	Factor of evaporation		1.181
32.	Water evaporated per hour(F&a 212 deg.)	lbs.	43795
33.	Quality of steam	%.	

34.	Horse Power Builders' Rating........................		650
35.	Boiler horse power (Mean of Test).................		1269
36.	" " " (Max. Hour)		
37.	Percent rating (Mean of Test)......................		195.3
38.	Sq.Ft.water heating surface per H.P.(Mean of Test).		5.03
39.	Water evap.actual per lb.coal as fired..........	lbs	8.87
40.	" " " " " dry coal................	lbs	9.07
41.	" " f&a 212° per lb.coal as fired........	lbs	10.50
42.	" " f&a 212° per lb.dry coal.............	lbs	10.73
43.	" " f&a 212° per lb.combustible..........	lbs	12.59

44. Wt.of gas per lb.Coal.Fur. 15.14 lbs. Flue 18.88 lbs.
45. Percentage of excess air " 47.5 % " 85.8 %
46. Cinders (a)weight 1001 (b) %coal fired................ 3
47. Carbon in Cinders percent coal fired.................% 2

HEAT BALANCE PER LB. COAL FIRED.

48.	Heat per lb. coal fired	Btu	13785
49.	Heat absorbed by water in boiler..................	Btu	9344
50.	Heat absorbed by steam in boiler(superheat).......	Btu	841

NECESSARY LOSSES.

51.	Heat absorbed by moisture & H_2O from burned H to Tp,.	Btu	401
52.	Heat absorbed by theoretical amt.dry gases up to Tp..	Btu	663
53.	Heat available for unit............................	Btu	12721
54,	Highest theoretical efficiency......................	%	92.4

FURNACE AND GRATE LOSSES.

55.	Heat loss due to combustible in ash................	Btu	429
56.	Heat absorbed by excess air up to Tp................	Btu	332
57.	Heat loss due to production of CO....................	Btu	
58.	Heat loss due to production of Cinders	Btu	290
59.	Heat available fof boiler...........................	Btu	11670
60.	Furnace and grate efficiency........................	%	91.8

BOILER LOSSES.

61.	Heat loss due to temp. of gases above Tp............	Btu	670
62.	Heat loss due to air leakage through boiler setting..	Btu	440
63.	Heat loss due to radiation and unaccounted for	Btu	375
64.	Boiler efficiency....................................	%	87.3
65.	Combined efficiency..................................	%	73.9

REPORT OF BOILER TEST WITH ANALYSIS OF HEAT LOSSES.

1.	Run from		8 A.M. to 4 PM
2.	Duration of test		eight hours
3.	No. of boilers used		one
4.	Type of boiler		W.T.
5.	No. of tubes		
6.	Diameter of tubes		4"
7.	Water Heating Surface	Sq. Ft.	6386
8.	Superheating Surface	Sq. Ft.	760
9.	Grate Surface	Sq. Ft.	115
10.	Ratio Grate Surface to Water Heating Surface	1 to .	55.5
11.	Steam gauge pressure	lbs.	195.6
12.	Atmospheric pressure	lbs.	14.7
13.	Absolute steam pressure	lbs.	210.3
14.	Draft suction at uptake	inches	.715
15.	Draft suction over fire	inches	.347
16.	Draft pressure under fire	inches	
17.	Avg. temp. boiler room	°F	70
18.	" " flue gases	°F	551
19.	" " feed water	°F	194
20.	" " steam.....Tp. 386.1...Ts......	°F.	557

21. Name of Fuel. West Virginia Semi-Bituminous.

22. Size of Fuel. Slack.

PROXIMATE ANALYSIS					B.tu.	ULTIMATE ANALYSIS		
H_2O	V.M.	F.C.	Ash	S.	per pound	C.	H.	S.
					fired. 13620.			
2.8	17.4	70.2	9.6		dry .. 14010.	73.9	3.8	
					comb.. 15550.			

ASH		FLUE GAS.				
% Comb. in Refuse	Refuse % Coal Fired		CO_2	O	CO	N etc.
	12.60	1st pass	17.2	1.2	0.1	81.5
23.8	Refuse % Dry Coal 12.9	flue	11.0	8.0	0.1	80.7

23.	Coal burned total run actual	lbs.	26568
24.	Coal burned per hour actual	lbs.	3321
25.	Coal burned per hour dry	lbs.	3228
26.	Coal burned per hour per sq.ft.g.s.actual	lbs.	28.88
27.	Total weight of refuse	lbs.	3347.5
28.	Total weight of combustible	lbs.	22423.5
29.	Water evap. total run actual	lbs.	220128
30.	" " per hour actual	lbs.	27516
31.	Factor of evaporation		1.17
32.	Water evaporated per hour (F.&a. 212 deg.)	lbs.	32111
33.	Quality of steam	%.	

34. Horse Power Builders' Rating........................ 650
35. Boiler horse power (Mean of Test).................. 931
36. " " " (Max.hr.)........................
37. Percent rating (Mean of Test)........................ 143.2
38. Sq.ft.water heating surface per H.P.(Mean of T.).... 6.71

39. Water evap. actual per lb.coal as fired..........lbs 8.28
40. Water evap.actual per lb.dry coal.................lbs 8.52
41. Water evap.f.&a.212° per lb.coal as fired.......lbs 9.67
42. Water evap.F.&a.212° per lb.dry coal.............lbs 9.95
43. Water evap.F.&a.212° per lb.combustible.........lbs 11.66

44. Wt.of gas per lb.coal Fur. 11.60 lbs. Flue 16.95 lbs
45. Percentage of excess air " 16.8 % " 74.3 %
46. Cinders (a) weight.797..(b)% coal fired............ 3.0
47. Carbon in Cinders percent coal fired...............% 2.0

HEAT BALANCE PER LB. COAL FIRED.

48. Heat per lb. coal fired............................Btu 13620
49. Heat absorbed by water in boiler..................Btu 8590
50. Heat absorbed by steam in boiler (superheat).....Btu 790

NECESSARY LOSSES.

51. Heat absorbed by moisture & H_2O from burned H to Tp, Btu,443
52. Heat absorbed by theoretical Amt.dry gases up to Tp, Btu,659
53. Heat available for unit............................. Btu,12518
54. Highest theoretical efficiency...................... %,91.9

FURNACE AND GRATE LOSSES.

55. Heat loss due to combustible in ash..............Btu 498
56. Heat absorbed by excess air up to Tp..............Btu 117
57. Heat loss due to production of CO..................Btu 63
58. Heat loss due to production of Cinders............Btu 290
59. Heat available for boiler..........................Btu 11550
60. Furnace and grate efficiency.........................% 92.3

BOILER LOSSES.

61. Heat loss due to temp. of gases above Tp............Btu 463
62. Heat loss due to air leakage through boiler setting.Btu 617
63. Heat loss due to radiation and unaccounted for .....Btu 1117
64. Boiler efficiency.......................................% 81.2
65. Combined efficiency....................................% 68.85

REPORT OF BOILER TEST WITH ANALYSIS OF HEAT LOSSES.

1. Run from		8 AM -4 PM
2. Duration of test		8 hrs.
3. No. of boilers used		one
4. Type of boiler		W.T.
5. No. of tubes		
6. Diameter of tubes		4"
7. Water heating surface	Sq.Ft	6386
8. Superheating Surface	Sq.Ft	760
9. Grate Surface	Sq.Ft	115
10. Ratio Grate Surface to Water Heating Surface	1 to	55.5
11. Steam gauge pressure	lbs	200.4
12. Atmospheric pressure	lbs	14.7
13. Absolute steam pressure	lbs	215.1
14. Draft suction at uptake	inches	.986
15. Draft suction over fire	inches	.492
16. Draft pressure under fire	inches	0.0
17. Avg. temp. boiler room	°F	90.1
18. " " flue gases	°F	592.5
19. " " feed water	°F	173.1
20. " " steam, Tp..388..... Ts	°F	560.2

21. Name of Fuel. . West. Virginia Semi-Bituminous . . . .

22. Size of Fuel. . Slack . . . .

PROXIMATE ANALYSIS					Btu per pound	ULTIMATE ANALYSIS		
H_2O	V.M.	F.C.	Ash	S.		C.	H.	S.
2.4	16.3	72.4	8.9		fired 13805			
					dry 14144	78.0	3.54	
					comb. 15563			

ASH		FLUE GAS				
% Comb. in Refuse			CO_2	O	CO	N etc.
20.15	Refuse % Coal Fired 11.13	1st pass	8.2	11.6	0.0	80.2
	Refuse % Dry Coal 11.4	Flue	7.0	12.9	0.0	80.1

23. Coal burned total run actual	lbs	30816
24. Coal burned per hour actual	lbs	3852
25. Coal burned per hour dry	lbs	3759
26. Coal burned per hour per sq.ft.g.s.actual	lbs	33.49
27. Total Weight of refuse	lbs	3430
28. Total weight of combustible	lbs	25718
29. Water evap. total run actual	lbs	243160
30. " " per hour actual	lbs	30395
31. Factor of evaporation		1.19
32. Water evaporated per hour (F&a. 212 deg.)	lbs	36170
33. Quality of steam	%	

34. Horse Power Builders' Rating........................ 650
35. Boiler horse power (Mean of Test).................... 1047
36. " " " (Max.Hour)......................
37. Percent rating (Mean of Test)........................ 161
38. Sq.Ft.water heating surface per H.P.(Mean of test).. 6.1

39. Water evap. actual per lb.coal as fired..........lbs 7.89
40. Water evap. actual per lb. dry coal..............lbs 8.08
41. Water evap. f&a 212° per lb.coal as fired........lbs 9.39
42. Water evap. f&a 212° per lb.dry coal.............lbs 9.62
43. Water evap. f&a 212° per lb.combustible..........lbs 11.25

44. Wt.of gas per lb. Coal Fur. 23.59 lbs. Flue 27.3 lbs.
45. Percentage of excess air " 142 % " 182.2%
46. Cinders (a) weight 924 (b) % Coal fired.............. 3.0
47. Carbon in Cinders percent coal fired................% 2.0

HEAT BALANCE PER LB. COAL FIRED.

48. Heat per lb. coal fired...........................Btu 13805
49. Heat absorbed by water in boiler ....Btu 8350.6
50. Heat absorbed by steam in boiler (superheat)......Btu 761.4

NECESSARY LOSSES.

51. Heat absorbed by moisture & H_2O from burned H up to Tp,Btu.404.3
52. Heat absorbed by theoretical amt.dry.gases up to Tp,.. Btu 659.2
53. Heat available for unit................................ Btu 12741.5
54. Highest theoretical efficiency..........................% 92.3

FURNACE AND GRATE LOSSES.

55. Heat loss due to combustible in ash.................Btu 379.55
56. Heat absorbed by excess air up to Tp................Btu 936.6
57. Heat loss due to production of CO...................Btu
58. Heat loss due to production of Cinders..............Btu 290
59. Heat available for boiler ....Btu 11148
60. Furnace and grate efficiency..........................% 87.5

BOILER LOSSES.

61. Heat loss due to temp. of gases above Tp............Btu 1130
62. Heat loss due to air leakage through boiler setting.Btu 445.4
63. Heat loss due to radiation and unaccounted for......Btu 460.6
64. Boiler efficiency.....................................% 81.7
65. Combined efficiency...................................% 66.0

REPORT OF BOILER TEST WITH ANALYSIS OF HEAT LOSSES

1.	Run from		8 AM-4 PM
2.	Duration of test		eight hrs.
3.	No. of boilers used		one
4.	Type of boiler		B & W
5.	No. of tubes		
6.	Diameter of tubes		4"
7.	Water heating surface	Sq.Ft.	6386
8.	Superheating surface	Sq.Ft.	760
9.	Grate surface	Sq.Ft.	115
10.	Ratio Grate surface to water heating surface	1 to..	55.5
11.	Steam gauge pressure	lbs.	201.5
12.	Atmospheric pressure	lbs.	14.7
13.	Absolute steam pressure	lbs.	216.2
14.	Draft suction at uptake	inches	.975
15.	Draft suction over fire	inches	.467
16.	Draft pressure under fire	inches	
17.	Avg.temp.boiler room	°F	90
18.	" " flue gases	°F	582
19.	" " feed water	°F	178.6
20.	" " steam Tp. 388.5 Ts	°F	558

21. Name of fuel. Zeigler County, Illinois..

22. Size of fuel. Slack.

PROXIMATE ANALYSIS							ULTIMATE ANALYSIS		
H_2O	V.M.	F.C.	Ash	S.	Btu per pound		C.	H.	S.
9.64	30.50	48.81	11.05		fired	11447			
					dry	12667	71.07	4.00	1.76
					comb.	14433			

ASH		FLUE GAS				
% Comb.in Refuse	Refuse %		CO_2	O	CO	N etc.
26.5	Refuse % Coal Fired 13.98	1st pass	12.4	7.6	0.8	79.4
	Refuse % Dry Coal 15.5	flue	10.3	9.6	0.6	79.5

23.	Coal burned total run actual	lbs.	42160
24.	Coal burned per hour actual	lbs.	5270
25.	Coal burned per hour dry	lbs.	4762
26.	Coal burned per hour per sq.ft.g.s.actual	lbs.	45.82
27.	Total weight of refuse	lbs.	5868.6
28.	Total weight of combustible	lbs.	30962.6
29.	Water evap.total run actual	lbs.	262724
30.	" " per hour actual	lbs.	32840.5
31.	Factor of evaporation		1.183
32.	Water evaporated per hur(F&a 212 deg.)	lbs.	38850
33.	Quality of steam	%	

34. Horse Power Builder's rating.................... 650
35. Boiler Horse Power (Mean of Test)............... 1127
36. Boiler Horse Power (Max.Hr.)....................
37. Per cent rating (Mean of Test).................. 1734
38. Sq.Ft.Water heating surface per h.p.(Mean of T.) 5.66

39. Water evap. actual per lb.coal as fired.....lbs 6.23
40. " " actual per lb.dry coal...........lbs 6.90
41. " " F&a 212° per lb.coal as fired.....lbs 7.37
42. " " F&a 212° per lb.dry coal...........lbs 8.16
43. " " F&a 212° per lb.combustible.......lbs 10.04

44. Wt.of gas per lb.Coal Fur. 14.11 lbs. Flue 16.6 lbs.
45. Percentage of excess air " 53 % " 84 %...
46. Cinders (a)weight 1264.8 (b)% coal fired........... 3
47. Carbon in Cinders percent coal fired...............% 2

HEAT BALANCE PER LB. COAL FIRED

48. Heat per lb. coal fired ....Btu 11447
49. Heat absorbed by water in boiler.................Btu 6557.0
50. Heat absorbed by steam in boiler(superheat).....Btu 594.8

NECESSARY LOSSES.

51. Heat absorbed by moisture & H_2O from burned H up to Tp,Btu 539.3
52. Heat absorbed by theoretical amt.dry gases up to Tp....Btu 592.2
53. Heat available for unit..................................Btu 10315.5
54. Highest theoretical efficiency..............................% 90.1

FURNACE AND GRATE LOSSES.

55. Heat loss due to combustible in ash..................Btu 495.4
56. Heat absorbed by excess air up to Tp..................Btu 315.4
57. Heat loss due to production of CO.....................Btu 369.2
58. Heat loss due to production of Cinders...............Btu 290
59. Heat available for boiler..............................Btu 8845.5
60. Furnace and grate efficiency............................% 85.7

BOILER LOSSES.

61. Heat loss due to temp. of gases above Tp.............Btu 632.7
62. Heat loss due to air leakage through boiler setting..Btu 297.5
63. Heat loss due to radiation and unaccounted for.......Btu 763.5
64. Boiler efficiency...% 80.8
65. Combined efficiency......................................% 62.48

IX. TABULATIONS OF HEAT BALANCES.

COAL									
	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS		B.t.u. VALUE PER POUND		
NO.	MOISTURE	VOL. M	FIX. CARB	ASH	C.	H.	AS FIRED	DRY	COMB.
1	2.8	17.4	70.2	9.6	73.9	3.8	13620	14010	15550
2	3.0	17.9	69.4	9.7	75.5	3.9	13610	14030	15600
3	3.8	15.6	70.7	9.9	72.9	3.54	13380	13910	15510
4	3.0	18.4	67.6	11.0	72.1	4.07	13370	13780	15550
5	3.0	16.7	74.0	6.3	79.2	3.64	14133	14571	15590
6	3.2	18.3	66.4	12.1	71.5	3.90	13053	13485	15410
7	2.8	17.4	69.6	10.2	75.7	3.73	13557	13948	15590
8	1.4	16.2	72.9	9.5	77.8	3.75	13788	13985	15475
9	3.2	16.6	68.7	11.5	71-5	3.88	12999	13429	15240
10	3.8	15.9	70.3	10.0	74.1	3.65	13371	13899	15510
11	1.6	16.1	74.0	8.3	78.9	3.54	14027	14255	15570
12.	2.2	16.2	72.7	8.9	78.0	3.54	13785	14095	15500
13	2.6	17.8	70.4	9.2	75.6	3.91	13692	14059	15530

LB. GAS PER LB COAL FIRED.			PERCENT EXCESS AIR		HEAT BALANCE PER POUND OF COAL AS FIRED — B.T.U. AND % EFFICIENCY.						
								NECESSARY LOSSES			
NO.	FCE.	FLUE	FCE.	FLUE	HEAT PER LB. OF COAL AS FIRED	ABSORBED BY THE WATER IN BOILER	ABSORBED BY THE STEAM IN SUPR. HTR.	ABSORBED BE THE MOISTURE & H_2O FROM H UP TO Tp	ABSORBED BY THEORET AMT. OF DRY GAS UP TO Tp	AVAILABLE FOR THE UNIT	HIGHEST THEORET EFFICIENCY
1	11.60	16.95	16.8	74.3	13620	8590	790	443	659	12518	91.9
2	14.46	17.75	43.3	78.0	13610	8914	656	456	675	12479	91.7
3	12.37	17.09	27.0	78.4	13380	8300	620	424	637	12319	92.1
4	16.20	18.60	67.9	92.9	13370	8671	749	471	624	12275	91.8
5	18.13	20.39	73.9	96.5	14133	9295	845	429	705	12999	92.0
6	18.0	18.78	66.0	96.0	13053	9060	835	453	614	11986	91.8
7	16.24	19.69	65.5	102.4	13557	8689	798	432	647	12478	92.0
8	15.1	19.7	47.0	94.0	13788	8119	844	415	663	12710	92.2
9	14.37	18.72	50.0	97.7	12999	8816	894	449	604	11946	91.9
10	16.54	20.03	68.7	106.0	13371	8095	655	438	661	12272	91.8
11	12.0	19.65	12.8	89.7	14021	9534	866	391	655	12981	92.6
12	15.14	18.88	47.5	85.8	13785	9344	841	401	663	12721	92.4
13	12.5	20.7	22.1	103.4	13642	9009	701	443	626	12623	92.2

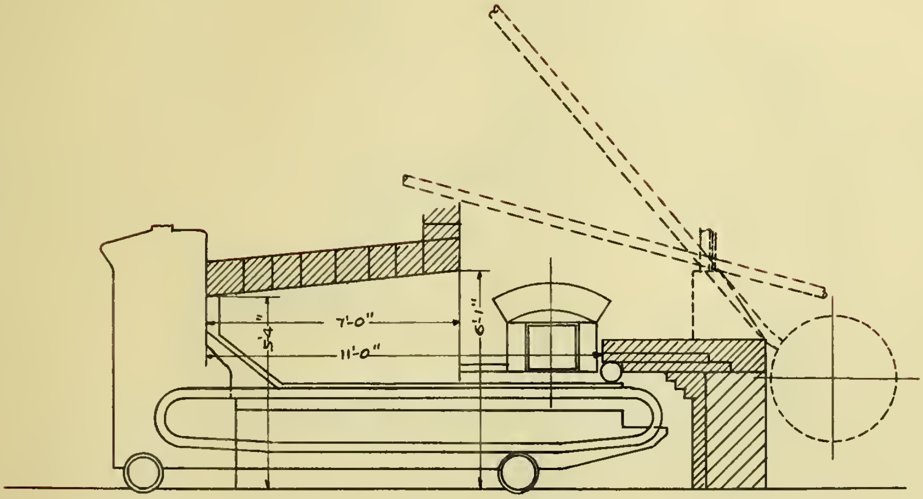
WATER PER HOUR – POUNDS							STEAM		
NO.	TOTAL ACTUAL	EQUIVALENT f.&a. 212° F.					PRESS. POUNDS SQ.IN. GAUGE	TEMP F°	SUPER HEAT F°
		TOTAL	PER LB. AS FIRED	PER LB. DRY COAL	PER LB. COMB.	PER SQ FT HEAT. SURF.			
1	27516	32111	9.67	9.95	11.04	5.03	195.6	557.0	170.9
2	30783	35093	9.87	10.16	11.29	5.50	194.6	517.5	131.8
3	22977	26400	9.20	9.57	10.65	4.13	197.0	521.5	134.8
4	28941	33658	9.71	10.01	11.28	5.27	196.7	545.9	159.3
5	31099	36125	10.45	10.77	11.52	5.66	198.4	554.9	167.7
6	31219	36373	10.20	10.52	12.03	5.70	194.9	553.3	167.5
7	25148	29282	9.78	10.06	11.24	4.59	195.4	555.8	169.8
8	25887	30365	9.24	9.37	10.37	4.75	197.6	582.5	195.6
9	27605	32296	10.01	10.34	11.74	5.06	200.9	557.5	189.2
10	28667	33110	9.02	9.38	10.46	5.19	197.7	532.6	147.6
11	34628	40728	10.72	10.40	11.90	6.39	197.9	557.1	170.1
12	37020	43795	10.50	10.73	11.80	6.85	199.7	557.0	169.3
13	37156	43023	10.01	10.28	11.35	6.74	198.1	529.0	141.9

	TEMPERATURE F°			DRAFT INS. WATER		BOILER HORSE POWER			CINDERS PERCENT OF COAL FIRED	CARBON IN CINDER PERCENT OF THE COAL FIRED
NO.	FEED WATER	BOILER ROOM	FLUE GASES	OVER FIRE	FLUE	AVERAGE FOR TEST	MAX. HOUR	PERCENT RATING		
1	194.0	70	551.0	.347	0.715	931	1005	143.2	3	2
2	201.2	70.3	528.4	0.41	0.760	1018	1125	156.5	3	2
3	194.3	79.0	518.0	0.33	0.580	765	830	117.6	3	2
4	192.5	80.0	562.8	0.387	0.756	976	1112.5	150.1	3	2
5	198.3	77.5	572.0	0.410	0.774	1047	1091	161.0	3	2
6	195.9	85.8	556.0	0.429	0.766	1054	1117	162.2	2	1.5
7	196.3	78.8	553.6	0.321	0.576	850	952	130.6	3	2
8	200.9	86.6	553.7	0.427	0.750	880	913	135.5	3	2
9	201.5	89.6	565.3	0.406	0.661	936	1038	144.0	3	2
10	194.6	74.3	514.0	0.495	0.884	960	1020	147.6	3	2
11	183.9	98.2	563.0	0.60	0.996	1182	1286	182.0	3	2
12	178.5	89.3	579.3	0.562	0.023	1269	1363	195.3	3	2
13	189.3	96.2	529.7	0.557	0.975	1247	1288	191.0	3	2

ASH			FLUE GAS %				COAL PER HOUR		
NO.	% COMB IN ASH	REFUSE PERCENT COAL FIRED	CO_2	O_2	CO	N. ETC.	AS FIRED	DRY COAL	PER SQ FT. GRATE SURFACE
1	23.8	12.60	17.2 10.2	1.2 8.0	0.1 0.1	81.5 80.7	3321	3228	28.88
2	21.9	12.42	13.7 10.8	3.2 7.5	0.0 0.0	83.1 81.7	3558	3450	30.90
3	19.7	12.33	15.4 10.6	1.6 7.2	0.3 0.2	82.7 82.0	2870	2760	24.96
4	20.4	13.82	11.3 9.8	7.9 8.4	0.15 0.0	80.65 81.8	3467	3362	30.15
5	24.7	8.36	11.0 9.7	7.5 8.2	0.2 0.1	81.3 82.0	3457	3353	30.85
6	16.6	14.5	11.5 9.7	6.3 9.2	0.1 0.0	82.1 81.1	3566	3453	31.00
7	28.6	14.3	13.3 9.2	6.1 8.8	0.4 0.2	82.2 81.8	2994	2910	26.00
8	22.7	12.3	13.1 9.8	3.9 9.4	0.4 0.15	82.6 80.65	3286	3240	28.56
9	18.4	14.1	13.0 9.6	4.1 9.1	0.0 0.0	82.9 81.3	3225	3122	28.04
10	18.4	12.25	11.4 9.3	7.1 9.4	0.1 0.0	81.4 81.3	3671	3521	31.90
11	18.2	10.15	18.0 10.2	0.9 8.2	0.0 0.0	81.1 81.6	3803	3740	33.06
12	22.35	11.46	13.3 10.4	5.7 8.0	0.1 0.0	80.9 81.0	4172	4080	36.28
13	20.55	11.60	16.4 9.2	2.0 9.9	0.0 0.0	81.6 80.9	4296	4185	37.36

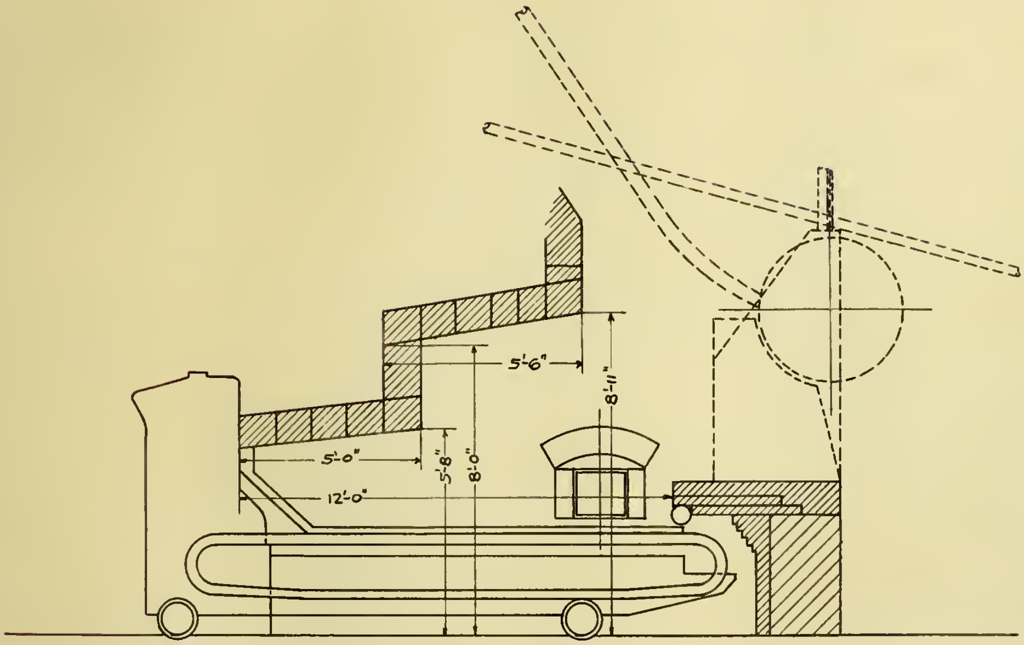
HEAT BALANCE PER POUND OF COAL AS FIRED — B.T.U. AND % EFFICIENCY											
FURNACE AND GRATE LOSSES.							BOILER LOSSES				
NO.	THROUGH GRATES WITH ASH	ABSORBED BY EXCESS AIR UP TO T_D	DUE TO PRODUCTION OF CO	DUE TO PRODUCTION OF CINDERS	AVAILABLE FOR BOILER	FURNACE AND GRATE EFFICIENCY	DUE TO TEMP. OF GASES ABOVE T_D	AIR LEAKAGE THROUGH SETTING	RADIATION AND UNACCOUN'D FOR	BOILER EFFICIENCY	COMBINED EFFICIENCY
1	498	117	63	290	11550	92.3	436	617	1117	81.2	68.85
2	457	313	0	290	11419	91.5	474	366	1009	83.8	70.30
3	415	182	129	290	11303	91.8	373	498	1512	78.9	66.6
4	479	460	0	290	11046	90.0	658	273	695	85.2	70.4
5	341	545	78	290	11745	90.5	780	268	557	86.3	71.7
6	421	438	0	217	10910	91.1	628	312	75	90.6	75.8
7	667	451	150	290	10920	87.6	630	397	406	86.9	70.0
8	468	319	112	290	11521	90.6	576	524	1458	77.8	65.0
9	448	326	0	290	10882	91.1	585	496	91	89.2	74.7
10	388	482	0	290	11112	90.5	489	369	1504	78.8	65.4
11	319	89	0	290	12283	94.6	483	854	546	84.7	74.1
12	429	332	0	290	11670	91.8	670	440	375	87.3	73.9
13	406	150	0	290	11777	93.3	407	852	808	82.4	70.9

X. ILLUSTRATIONS OF FURNACE DESIGN.



DESIGN OF FURNACE WITH CHAIN GRATE STOKER SUITABLE FOR BURNING SEMI-BITUMINOS COAL AT RATES UP TO 40LBS. PER SQ.FT. PER HOUR.

FIG. 1



DESIGN OF FURNACE WITH CHAIN GRATE STOKER SUITABLE FOR BURNING HIGH VOLATILE COAL AT RATES UP TO 40LBS. PER SQ.FT. PER HOUR.

FIG. 2.